The Effectiveness of Motor Therapy Alone Versus Motor Therapy With a Minimal Pairs Component in the Remediation of Phonologic Processes

An Honors Thesis (HONRS 499)

by

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Abstract

Two children with phonologic disorders were treated, one with motor therapy alone, and the other with motor therapy including a minimal pairs component. The procedures of both methods are reported and the results are described. Generalization was measured through a series of generalization probes designed specifically for each participant. There was generalization evidenced to untreated words in the treated process for Participant J, but these did not maintain. The generalization to the untreated process in Participant J may have been due to maturation. There was no generalization evidenced to untreated phonemes, words, or processes for Participant A.

Literature Review

Phonologic Processes

Ingham (1988) has defined phonologic processes as, "systematic sound changes that operate across a class of sounds or across sound sequences so that multiple members of the class are affected similarly," (p. 129). The criteria used to determine the presence and use of phonologic processes in this study were those used by McReynolds & Elbert (1981). These criteria are at least four opportunities for occurrence of the process and presence of the process in at least 20% of the opportunities.

When phonologic processes are present in the speech of phonologically disordered children, it often results in unintelligibility. One contributor to unintelligibility is homonymy, and quite often the result of phonologic process usage is an increased presence of homonymy in a child's speech. Homonymy can result from any number or combination of phonologic processes at work in a child's speech (Fokes, 1982, p.22). This occurs because of the neutralization of phonemic contrasts. For instance, if a child used the process of deleting final consonants, the words "bee" and "beet" would be neutralized to the homonym "bee."

Therapy based on phonologic processes is considered to be phonologic, or linguistic, in nature. Monahan (1986) claims that any child, "whose articulation errors are not limited to specific sounds, but instead are reflective of broad error patterns, would be an excellent candidate for a phonological approach" (p. 205).

Most often in a linguistic approach to therapy, methods are chosen in order to "facilitate the acquisition of appropriate sound contrasts and or sequences," (Bernthal & Bankson, 1998, p.333).

Minimal Pairs

One of the methods used to facilitate the acquisition of sound contrasts is a minimal pairs component in therapy. Blache (1982) states that, "when two words are essentially identical, and they differ by one feature or sound property, we say the words are 'minimal-pair' words" (p. 62). More generally, Finegan (1994) states that any two words differing by only one sound constitute a minimal pair (p. 56). Many studies involving minimal pairs have used them in the more general sense, not limiting them only to words differing by one feature or sound property, as Blache states. Instead, the term minimal pairs has been applied to words differing by any *one sound* (Hoffman, Norris, Monjure, 1990; Monahan, 1986; Saben & Ingham, 1991; Tyler, Edwards, Saxman, 1987; Weiner, 1981; Young, 1983;). For instance, if a child used the process of stopping, homonymy would result between the words "fun" and "pun", so that they would both be pronounced, "pun." Or, the words, "vest" and "best" would both become the homonym "best."

Naturally, remediating homonymy due to phonologic disorders in children through minimal pairs therapy presupposes the children's willingness, desire, and ability to change their phonologic systems to match those of the adult. Fokes (1982) states that this is not necessarily the case. Some children remain satisfied with their attempts to be understood and make no efforts to change their phonologic processes (p. 22).

Minimal pairs therapy is meant to make the child aware of the breakdown in his/her communication due to homonomy. So, when a child who uses final consonant deletion says "two," instead of "tooth," and is misunderstood, it is assumed he/she will experience frustration and will attempt to remediate misunderstandings by altering production of a word to produce phonemic contrasts.

In the literature, there are essentially two different ways to teach minimal pair contrasts. In the first, the clinician points to the target word in a pair, and the child says the name of the picture. If the child does not use a phonemic contrast and says the pair word instead of the target word, the clinician points out to the child that he/she just said the other word in the pair and asks him/her to try the target word again. This method was used by Tyler, Edwards, and Saxman (1987), and Young (1981).

The second method is one in which a communication breakdown is created by asking the child to be the teacher. The child says the name of the one word and then the other in a pair, and as he/she says a word, the clinician points to it. Inevitably, when attempting the target word, the child will neutralize the contrast and say the pair word instead, and the clinician's finger will point to (in the child's mind) the "wrong" word. At this point, the clinician informs the child of the contrast needed in order to communicate the target word. This method, or some modification of it, was used by Blache (1982), Blache, Parsons, and Humphreys (1981), Monahan (1986), and Weiner (1981).

Minimal pairs have been used in research along with motor components (Balache, Parsons, and Humphreys, 1981; Hoffman, Norris, and Monjure 1990; Monahan, 1986; Saben & Ingham 1991; Tyler, Edwards, and Saxman 1987; Weiner 1981). They have also been used without motor components (Young, 1983), and along with auditory bombardment and with perception training (Monahan, 1986).

Blache, Parsons, and Humphreys (1981) used word pair contrasts to treat distinctive feature differentiation and found that, "generalization occurred in the untrained feature classes" (p. 294). This study did not, however, use a consistent generalization probe to measure articulation changes before, during, and after administration of treatment. The *Fisher-Logemann Test of Articulation Competence* (Fisher & Logemann, 1971) and the *Photo Articulation Test* (Pendergast, Dickey, Selman, & Soder, 1969) were used alternatingly for pre-, and post-testing. In addition, motor components (auditory discrimination and verbal models) were used along with minimal pair contrasts in this study so it could not be shown *which* component of therapy improved the participants' articulation.

Hoffman, Norris, and Monjure (1990) contrasted a minimal pairs-based therapy (including a motor component of verbal models) to a whole language approach that was without specific attention given to the details of phonologic production. This study showed similar results, phonologically, in both participants

In Monahan (1986), four participants with moderate/severe phonological disorders were treated using minimal-word-pair contrasts, auditory bombardment, perception training, and production training (motor component). The approach was, "effective in reducing the frequency of occurrence of all processes targeted." In addition, "Generalization of target patterns was noted in untrained words for all subjects" (p.199). These results, however, were not shown to have been due, exclusively, to the minimal pairs component of therapy.

In Saben and Ingham (1991) two children, both using phonologic processes, received treatment containing a minimal pairs component. Motor components had to be added to therapy for both participants to pass all treatment steps. Neither subject generalized to untreated words or phonemes in the targeted phonologic process, and although they both passed all treatment steps, it could not be shown that the minimal pairs components were any more effective than motor therapy would have been alone.

In Tyler, Edwards, and Saxman (1987) four children participated. Two participants received minimal pairs therapy, and two received a modified cycles procedure based on phonologic analyses. Both treatment approaches contained verbal models, and imitation. And, both procedures were "found to be effective and efficient, as evidenced by the elimination of up to three phonological processes within two and a half months for each subject" (p. 393). It cannot be determined from the study, however, which parts of each procedure were "effective and efficient," or whether the minimal pairs components of the minimal pairs based procedure were effective.

In Weiner (1981) two children exhibiting use of phonologic processes were treated using a minimal pairs – based procedure, in which suppression of the process was counted as a correct response, and verbal models (motor component) were employed as error strategies. Although the procedure proved very effective for suppression of the processes in both participants, it could not be shown whether the minimal pairs component or presence of motor components was the factor causing the effectiveness of the procedure overall.

Research Questions

It has not been determined, as is the purpose of this study, whether a minimal pairs component in motor therapy is more effective and efficient than motor therapy would be alone, with no linguistic component involved. This study will explore the effectiveness and efficiency of a minimal pairs component in therapy by addressing the following questions. Does a minimal pairs component to motor therapy promote generalization to untreated phonemes/words better than motor therapy alone? And, does minimal pairs therapy promote phonemic contrasts between minimal pairs? Further, does it promote *correct* phonemic contrasts?

Method

Participants

Two children, ages 4;3 and 4;0, served as participants in this study. Both participants met the following selection criteria: at least three phonological processes that met criteria (McReynolds & Elbert, 1981), no organic problems, or history thereof, that are known to impact phonology, hearing within normal limits, monolingual English home environments, and scores within normal limits on an oral mechanism examination (OSMSE-R) (St Louis & Ruscello, 1987).

Pretreatment Data Collection and Analysis.

The Test for Auditory Comprehension of Language-Revised (TACL-R) (Carrow-Woolfolk, 1985) and an informal articulation assessment probe were administered to both participants. The assessment probe consisted of spontaneous picture naming of 88 words. The 88 words contained a minimum of four opportunities to produce every consonant in both the releasing and arresting positions except those that rarely or never occur in one or both of those positions. (See Appendix.) A phonologic process analysis and a phonetic inventory analysis were then conducted for each participant based on the results of the assessment probe. The criteria used to determine the phonologic processes present were that the process had to have the opportunity to occur at least four times, and the process had to have occurred in at least 20% of the opportunities present (McReynolds & Elbert, 1981). For the phonetic inventory analysis, phonemes were included in the phonetic inventory if they occurred at least two times within a given syllable position. Stimulability testing was conducted in nonsense syllables in the releasing and arresting positions for those phonemes not present in the phonetic inventory. Five different nonsense syllables were used for stimulability testing for each consonant in the releasing and/or arresting positions with a variety of vowels (front, back, high, and low). Stimulability testing was conducted by asking the participant to imitate the syllable produced by the clinician. If the participant could not produce the consonant correctly on the first try, another verbal model was given. If this still did not evoke the correct production, minimal phonetic placement cues were provided. If the participant still could not produce the consonant, it was recorded as being nonstimulable.

Participant J. Participant J was 4 years, 3 months (4;3) at the beginning of his participation in this study. He scored in the seventh percentile on the TACL-R (Carrow-Woolfolk, 1985), indicating the presence of a receptive language disorder. A phonologic process analysis revealed the presence of five phonologic processes in J's speech (see Table 1). A phonetic inventory analysis revealed that /f,v,l,r/ were not present in his phonetic inventory in the releasing position, and /g,f,v,tʃ,dʒ/ were not present in the arresting position. Stimulability testing revealed that J was not stimulable for /r/ or /l/ in the releasing position and /dʒ/ in the arresting position. He was stimulable for all other sounds missing from his phonetic inventory.

Participant A. Participant A was 4 years, 0 months (4;0) at the beginning of her participation in this study. She scored in the 70th percentile on the TACL-R, indicating receptive language skills within normal limits. A phonologic process analysis revealed the presence of five phonologic processes in A's speech (see Table 2). Her speech was characterized by a severely reduced phonetic inventory. Only /t,b,d,k,g,h,m,n/ were present in the releasing position, and no consonant phonemes were present in the arresting position. Stimulability testing revealed that Participant A was stimulable for /p,f,v/ in the releasing position and /b,t,p/ in the arresting position. She was not stimulable for any other consonant that was missing from her phonetic inventory.

Research Design

Both within and between subjects designs were used in this study. A within subjects multiple baseline design across phonologic processes was used to demonstrate that treatment was responsible for the observed changes in speech sound production. A between subjects group comparison design was used to evaluate the effects of minimal pair stimuli used in treatment.

For the multiple baseline across processes design, generalization probes (see below) measuring two processes were administered three times before treatment began, once during treatment, and three times after treatment for each participant. Only one phonologic process was treated for each participant so that improvement in the treated processes could be attributed to treatment as long as the untreated phonologic processes remained at baseline levels.

For the group comparison design, Participant J received motor therapy only, while Participant A received motor therapy plus a minimal pairs component. The treatment procedures were identical except for the presence or absence of minimal pair stimuli (see Treatment). In addition, the processes chosen for treatment for the two participants affected the same number of phonemes, so that the differences in treatment efficacy could be attributed to the presence or absence of minimal pairs rather than some other variable.

Generalization Probes

A generalization probe was constructed for each participant to measure the use of two processes (one to be treated and one to be monitored). Each generalization probe contained a minimum of four opportunities for every phoneme (separately by position, if applicable) that could be affected by the two phonologic processes. None of the words on the generalization probes was used in treatment. Participant J's probe contained 56 words and Participant A's probe contained 50 words.

The generalization probes were administered to each participant three times before treatment began in order to establish baselines. The probes were also administered once during treatment and three times after treatment. The generalization probes were used for two purposes. First, they were used to demonstrate that treatment was responsible for improvements in speech sound production by measuring changes in the treated processes, while the untreated processes remained at baseline levels. Second, they were used to compare the relative effects of treatment with and without minimal pairs. Differences in treatment effects were examined for overall decrease in process usage, differences in generalization to untreated words, and differences in the amount of generalization to untreated phonemes.

Treatment Targets

One process was chosen to treat for each participant, and two phonemes affected by that process were directly treated. In addition, one process was chosen to monitor in addition to the process treated for each participant.

Participant J. Postvocalic Devoicing and Stopping of Dental Fricatives were the two processes chosen for Participant J, because they were the two processes occurring most frequently. Postvocalic Devoicing was chosen as the process to treat for Participant J, because it affected more phonemes than Stopping of Dental Fricatives. The two phonemes treated were /g/ and /v/. Neither phoneme was present in J's phonetic inventory, but he was stimulable for both. Five words were selected as treatment stimuli for each phoneme (see Table 3).

Participant A. Final Consonant Deletion of Fricatives and Stopping in the Releasing Position were the two processes chosen for Participant A, because they were the two processes occurring the most frequently that could also be treated using minimal pair therapy. Final Consonant Deletion of Fricatives was chosen to treat for Participant A, because it was the greatest contributor to the unintelligibility of her speech. The two phonemes treated were /v/ and /θ/. Neither phoneme was present in A's phonetic inventory, and she was not stimulable for either of them. Five picturable minimal pairs were selected as treatment stimuli for each phoneme (see Table 4.)

Treatment

The two different treatment procedures used in this study were identical except for the use of minimal pairs. Treatment without minimal pairs will be referred to as "Motor Therapy Alone," and treatment with minimal pairs will be referred to as "Motor Therapy Plus Minimal Pairs." For each participant, two phonemes from one phonologic process were targeted. Phonemes were taught serially with the administration of a generalization probe in between.

Tables 3 and 4 show the treatment steps that were used for both treatment approaches. The first step in both approaches was a receptive stimulus identification procedure in which the participant was required to point to the picture the experimenter named. The five words containing the treatment phoneme were used (e.g., the non-target words of the minimal pairs were not used for Participant A). Therapy advanced to Step 2 when 95% (19/20) accuracy was achieved. Step 2 in both approaches consisted of correct production of the target sound when given a verbal model. The same treatment words and pass criterion used in Step 1 were used in Step 2. All correct responses were reinforced verbally and with a token. Tokens were later traded in for small toys or playtime.

The difference between the therapy approaches occurred in Step 3. For Participant J (Motor Therapy Alone), Step 3 was identical to Step 2, except that no verbal model was provided. For Participant A (Motor Therapy Plus Minimal Pairs), Step 3A also consisted of spontaneous production of the treatment words without a verbal model; however, when 50% (10/20) accuracy was achieved, the minimal pair stimuli (Step 3B) were introduced.

Step 3B consisted of presenting Participant A with the two pictures in each minimal pair one at a time. The experimenter would then point at one of the pictures and ask her, "What is this?" When Participant A responded correctly, she was reinforced. If she did not correctly produce the target phoneme at the end of a word in which it was appropriate, the experimenter pointed out that she had said the other word rather than the one the clinician pointed to. Then the clinician would ask her to try the original word again. Pass criterion for this step was 90% (18/20) accuracy.

After pass criterion was met on Step 3 for both therapy approaches, a generalization probe was administered. Treatment was then conducted on the second phoneme for the same process.

Therapy was conducted in the same manner as described above for the second phoneme. (See Tables 3 & 4.)

Results

This study was designed to answer several questions. First, is motor therapy combined with a minimal pairs component more effective than motor therapy without the minimal pairs component? Second, does motor therapy with minimal pairs promote generalization to untreated phonemes/words better than motor therapy alone? Finally, does a minimal pairs component in motor therapy promote phonemic contrasts (and *correct* phonemic contrasts) better than motor therapy alone?

Treatment

Participant J. It should be noted that a branch step was added between Step 1 and Step 2 for the second phoneme treated (/v/). (See Table 7.) In this branch step, /v/ was trained in isolation, and Participant J was given verbal models and phonetic placement cues. This was a very brief branch step for Participant J. Participant J met final pass criterion for /g/ in 4 sessions and for /v/ in 8 sessions. Table 5 shows the number of sessions Participant J spent on each step of treatment.

Participant A. It should be noted that three branch steps were added between Step 1 and Step 2 for the first phoneme treated (/v/). (See Table 8.) In the first branch step (sublevel 1a), /v/ was trained in isolation, and Participant A was given verbal models and phonetic placement cues. In the second branch step (sublevel 1b), phonemes were trained in nonsense syllables, verbal models were given and phonetic placement cues and kinesthetic cues were given. In the third branch step (sublevel 1c), /v/ was trained in nonsense syllables, without a verbal model or any other cues. Participant A met final pass criterion for /v/ in 12.5 sessions, and for /θ/ in 8 sessions.

Some modifications were also made for the second phoneme taught (/θ/). In sublevel 1a, /θ/ was trained in isolation, the same as with /v/. When a criterion of 50% (6/12) accuracy was met, therapy continued to sublevel 1b. In this sublevel, phonemes were trained in nonsense syllables, the same as above. When a criterion of 60% (12/20) accuracy had been reached, therapy continued on to level 2. There was no sublevel 1c used in teaching /θ/ to participant A.

For a summary of the number of sessions spent to reach criterion for each level/sublevel of therapy for Participant A, see Table 6. Participant A reached final criterion for /v/ in words without a verbal model in a total of 12.5 sessions, and final criterion (same as above) for /θ/ in a total of 8.5 sessions.

Final criterion was reached for /θ/ at level 3A, before minimal pairs were ever attempted. For this reason, a modification was made in that a generalization probe was administered, and then therapy continued for two more sessions using minimal pairs, even though criterion had previously been met for that phoneme.

The increased number of sessions required for Participant A to reach final criterion are due to the additional therapy done with the phonemes in isolation and nonsense syllables, which was not necessary for Participant J.

Generalization to Untreated Words

Generalization to untreated words was measured through a series of generalization probes (consisting of 56 words for Participant J and 50 words for Participant A) containing a minimum of four opportunities for every phoneme that could be affected by two phonologic processes.

Participant J. Table 9 shows Participant J's usage of the process of postvocalic devoicing as a percent of opportunity through all the probes administered throughout the study. Postvocalic devoicing was the process treated for participant J. The phonemes /g/ and /v/ were directly treated. In three consecutive generalization probes administered before treatment began, /g/ was devoiced 75, 50, and 100% of the time. On the generalization probe that was administered immediately after treatment on /g/ (probe 4), /g/ was devoiced only 25% of the time. In the three generalization probes (probes 5, 6, and 7) administered after treatment on /v/, /g/ was devoiced 0, 50, and 100% of the time, respectively. This indicates that generalization to untreated words did occur, but it was not maintained.

In three consecutive generalization probes administered before treatment on /g/ began, /v/ was devoiced 25, 0, and 25% of the time, respectively. On the generalization probe that was administered immediately after treatment on /g/ (probe 4), /v/ was devoiced 50% of the time. In the three generalization probes (probes 5,6, and 7) administered after treatment on /v/, /v/ was devoiced 0, 0, and 50% of the time. This indicates that, like /g/,/v/ generalized to untreated words, but that generalization did not maintain.

<u>Participant A.</u> Table 10 shows Participant A's usage of the process of final consonant deletion of fricatives as a percent of opportunity through all the probes given throughout therapy. Final Consonant Deletion of Fricatives was the process treated for Participant A. The phonemes /v/ and /θ/ were directly treated. There was an extra generalization probe (probe 5) administered to Participant A, because she reached final criterion on /θ/ *before* the minimal pairs component was utilized in therapy. At this time, a generalization probe was administered, followed by two sessions of minimal pairs therapy, and then the final three generalization probes.

Neither /v/ nor /θ/ generalized to untreated words, as they were both deleted 100% of the time on every one of the eight generalization probes administered. In addition, there was no generalization at any point to untreated phonemes or to the process that was monitored (Stopping In the Releasing Position).

<u>Generalization to Untreated Phonemes</u>

<u>Participant J.</u> There was no generalization to untreated phonemes within the process of Postvocalic Devoicing; however, there was generalization to some phonemes affected by the process which was monitored, but was untreated (Stopping of Dental Fricatives). Particularly, there was generalization to /-f, -v, -θ/, all affected by this process in the arresting position.

The phoneme /-f/ was stopped in 100, 100, and 50% of opportunities before treatment of /g/, in 50% of opportunities before treatment on /v/, and in 0% of opportunities in each of the three probes administered after treatment finished.

The phoneme /-v/ was stopped in 100, 75, and 25% of opportunities before treatment of /g/, in 50% of opportunities before treatment on /v/, and in 0, 25, and 25% of opportunities in each of the three probes administered, respectively, after treatment had finished.

The phoneme /- θ/ was stopped in 100, 100, and 50% of opportunities before treatment of /g/, in 50% of opportunities before treatment on /v/, and in 0% of opportunities in each of the three probes administered after treatment had finished. (See Table 9.)

Participant A. Interestingly, after all treatment, except the minimal pairs component at the end, had been completed, Participant A began using /l/ (a phoneme which had not existed in her phonetic inventory during assessment) in the generalization probes and in spontaneous speech. In the generalization probe administered just before the minimal pairs component was introduced, Participant A used /l/ correctly in 20% (1/5) of opportunities for /l/ and /l/ clusters in the releasing position. In the last three generalization probes, she used /l/ correctly in 40% (2/5), 60% (3/5), and 80% (4/5) of opportunities for /l/ and/or /l/ clusters in the releasing position.

Other than the above-mentioned change in phoneme usage, Participant A did not generalize to any untreated phonemes.

Discussion

Participant J

With only two participants in this study, there are very few solid conclusions that may be drawn, and many questions left open to further research; however, there were several interesting occurrences in this study as well.

It cannot be determined with certainty what caused the fluctuation in Participant J's usage of postvocalic devoicing and stopping of dental fricatives. It is likely that the fluctuation seen in the use of postvocalic devoicing was simply an observation of the normal fluctuation in Participant J's use of that process. There may be a different explanation, though, for the fluctuation of use of stopping of dental fricatives, especially with regards to the arresting fricatives (/f,v, θ/). During three consecutive baseline probes before treatment, the percent process usage in all three of these phonemes decreased by at least 50%. One conclusion we may draw from this occurrence is that since the process was decreasing in usage *before* treatment began, it was not necessarily treatment, or treatment alone which remediated the percent process usage of stopping of dental fricatives. The remediation and generalization observed may have been due, at least in part, to maturation or some other unknown factor. This would make sense, because the generalization to these phonemes maintained throughout the three generalization probes after therapy was finished.

Participant A

Participant A showed no generalization to untreated words, phonemes, or processes. This does not necessarily mean, however, that treatment was without effect. Final Consonant Deletion of Fricatives was targeted for Participant A, and, although she never produced a final fricative in the untreated words in generalization probes, she did begin in the last three probes (probes 3-5) to add a vowel sound to the ends of words where fricatives should have been produced. For instance, instead of saying /di/ for "sing," she said /diə/. In generalization probes 3-5, she did this 21% (5/24), 29% (7/24), and 17% (4/24) of the time, respectively. (An opportunity equaled any word in the probe containing a final fricative singleton.) (See Table 11.)

The interesting thing about this occurrence is not necessarily *that* it was present (because presence of final fricatives had been taught throughout therapy), but that it began occurring immediately following the introduction of the minimal pairs component of treatment for /θ/, and that it occurred with relatively high and consistent frequency given the fact that it had never occurred previously. This seems to indicate that the minimal pairs training introduced, to Participant A, a linguistic knowledge of the presence of final consonants, which was *not* introduced through motor training alone.

Because of the limited number of participants in this study, the conclusions that can be drawn are, at best, speculative, and further study in this area would be enlightening.

Participant A had, at the beginning of her participation in this study, a significantly higher level of receptive language skills than Participant J, as measured by the Test for Auditory Comprehension of Language-Revised (TACL-R) (Carrow-Woolfolk, 1985). Participant A scored in the 70th percentile overall, a relatively high score compared to Participant J's 7th percentile ranking. Minimal pairs therapy was *not* done with Participant J for this reason, in addition to the fact that his vocabulary was extremely limited. It may be that higher receptive language skills/capabilities before and during minimal pairs treatment serve to augment therapy done in this manner, and that lower receptive language skills would frustrate or hinder such a therapy approach. This would seem to be in line with the currently held position that minimal pairs therapy is a language-based therapy. Further study in this area would be beneficial as well as fascinating.

Concrete conclusions cannot be drawn from this study about the effectiveness of a minimal pairs component in motor therapy versus motor therapy alone because of the striking differences between the two participants; however, it has opened up a number of interesting issues for further study/research, including the role of language abilities in the effectiveness of minimal pairs therapy.

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Table 1. J's Phonologic Processes Percent Usage During Assessment

Phonemes Dental Fricatives	**Process (%)** Stopping of Dental Fricatives	**Phonemes** Arresting Voiced	**Process (%)** Postvocalic Devoicing	**Phonemes** Clusters	**Process (%)** Cluster Reduction
/f-/	100	/-b/	25	/br-/	25
/v-/	100	/-d/	25	/sl-/	0
/θ-/	75	/-g/	75	/fr-/	0
/-f/	100	/-z/	60	/gr-/	0
/-v/	100	/-v/	25	/gl-/	0
/-θ/	100	/-dʒ/	50	/st-/	100
Overall	*96*	*Overall*	*44*	/sn-/	100
				/kr-/	0
				/kl-/	0
				/-st/	100
				Overall	*31*

Phonemes Releasing Voiceless Stops	**Process (%)** Prevocalic Voicing	**Phonemes** Releasing Affricates	**Process (%)** ST of Affricates (Releasing)
/p-/	50	/dʒ -/	25
/t-/	57	/tʃ -/	25
/k-/	14	*Overall*	*25*
Overall	*41*		

Table 2. A's Phonologic Processes Percent Usage During Assessment

Phonemes Releasing Voiceless Stops	**Process (%)** Prevocalic Voicing	**Phonemes** Phonemes	**Process (%)** Velar Assimilation (Releasing)
/p-/	100	/t-/	100
/t-/	100	/d-/	100
/k-/	50	/p-/	0
Overall	*83*	/t -/	100
		/f-/	100
		/v-/	0
		/s-/	50
		/l-/	100
		/eɪ-/	100
		Overall	*77*

Phonemes	**Process (%)**	**Phonemes**	**Process (%)**
Arresting Fricatives	FCD of Fricatives	Releasing Fricatives & Affricates	Stopping (Releasing)
/-f/	100	/θ-/	100
/-v/	100	/ð-/	----
/-θ/	100	/f-/	100
/-s/	100	/v-/	75
/-z/	100	/s-/	100
/-ʃ/	100	/z-/	75
/-ð/	----	/ʃ-/	75
/-ʒ/	----	/ʒ-/	----
Overall	*100*	/tʃ-/	100
		/dʒ-/	100
		Overall	*89*

Phonemes Clusters	**Process (%)** Cluster Reduction
/br-/	100
/sl-/	100
/fr-/	100
/gr-/	100
/gl-/	100
/st-/	100
/sn-/	100
/kr-/	100
/dl-/	100
/-st/	100
Overall	*100*

Table 3. Steps of Therapy for Participant J			
Step	**Stimulus**	**Response**	**Pass Criterion**
1	Pictures of five treatment words. Clinician says, "Show me ____."	Points to stimulus picture named	95% correct (19/20)
2	Pictures of five treatment words plus verbal model	Correct production of target phoneme	90% correct (18/20)
3	Pictures of five treatment words (no verbal model)	Correct production of target phoneme	90% correct (18/20)

Table 4. Steps of Therapy for Participant A			
Step	**Stimulus**	**Response**	**Pass Criterion**
1	Pictures of five treatment words. Clinician says, "Show me ____."	Points to stimulus picture named	95% correct (19/20)
2	Pictures of five treatment words plus verbal model	Correct production of target phoneme	90% correct (18/20)
3A	Pictures of five treatment words (no verbal model)	Correct production of target phoneme	50% correct (10/20)
3B	Pictures of minimal pair words Clinician points to each picture in the pair	Correct production of target phoneme in target word plus correct production of nontarget	90% correct (18/20)

Table 5. Total Number of Sessions per Treatment / Branch Step for Participant J

Steps	Target Phonemes	
	/g/	/v/
1) Receptive Stimulus ID pass criterion = 95%	.5	.5
1a) Isolation with verbal model	—	.5
2) Words with verbal model pass criterion = 90%	2	4.5
3) Words without verbal model pass criterion = 90%	2	3

Table 6. Total Number of Sessions per Treatment / Branch Step for Participant A

Steps	Target Phonemes	
	/v/	/θ/
1) Receptive Stimulus ID pass criterion = 95%	.5	.5
1a) Isolation with verbal model	3	1.5
1b) Syllables with verbal model	5	1.5
1c) Syllables without verbal model	.5	—
2) Words with verbal model pass criterion = 90%	2	2.5
3A) Words without verbal model pass criterion = 50%	.5	.5 *
3B) Minimal Pair Words without verbal model pass criterion = 90%	1.5	2

* Participant A achieved 90% in this half session, going beyond the 50% pass criterion.

Table 7. Steps of Therapy Plus Addition of Branch Steps for Participant J

Step	Stimulus	Response	Pass Criterion
1	Pictures of five treatment words. Clinician says, "Show me ____."	Points to stimulus picture named	95% correct (19/20)
1a*	Verbal model and phonetic placement cues of sound /-v/ in isolation	Correct production of target phoneme in isolation	50% correct (5/10)
2	Pictures of five treatment words plus verbal model	Correct production of target phoneme	90% correct (18/20)
3	Pictures of five treatment words (no verbal model)	Correct production of target phoneme	90% correct (18/20)

* see Results section for explanation of sublevels

Table 8. Steps of Therapy Plus Addition of Branch Steps for Participant A

Step	Stimulus	Response	Pass Criterion
1	Pictures of five treatment words. Clinician says, "Show me ____."	Points to stimulus picture named	95% correct (19/20)
1a*	Verbal model and phonetic placement cues (sound /-v/ & /-θ/ in isolation	Correct production of target phoneme in isolation	50% correct (5/10)
1b*	Verbal model, phonetic placement cues, and kinesthetic cues for sound in arresting position of, nonsense syllables /-v/ & /-θ/	Correct production of target phoneme in arresting position of nonsense syllables	50% correct (10/20)
1c♦*	Phonetic placement cues, and kinesthetic cues for sound in arresting position of nonsense syllables /-v/ (no verbal model)	Correct production of target phoneme in arresting position of nonsense syllables	50% correct (10/20)
2	Pictures of five treatment words plus verbal model	Correct production of target phoneme	90% correct (18/20)
3A	Pictures of five treatment words (no verbal model)	Correct production of target phoneme	50% correct (10/20)
3B	Pictures of minimal pair words Clinician points to each picture in the pair	Correct production of target phoneme in target word plus correct production of nontarget minimal pair word	90% correct (18/20)

* See Results section for explanation of sublevels.

♦ Branch Step not used when /   / was treated

Table 9. Participant J's Use of Postvocalic Devoicing and Stopping of Dental Fricatives Pre-, During, and Post – Treatment

Postvocalic Devoicing

				Treatment /-g/	Treatment /-v/		
Phonemes	Probe 1 (Baseline 1)	Probe 2 (Baseline 2)	Probe 3 (Baseline 3)	Probe 4 (Gen. 1)	Probe 5 (Gen. 2)	Probe 6 (Gen. 3)	Probe 7 (Gen. 4)
/-b/	25% (1/4)	75%	100%	25%	50%	75%	75%
/-d/	25% (1/4)	50%	100%	75%	50%	100%	100%
/-g/	75% (3/4)	50%	100%	25%	0%	50%	100%
/-z/	75% (3/4)	0%	75%	75%	100%	75%	100%
/-v/	25% (1/4)	0%	25%	50%	0%	0%	50%
/-dʒ/	50% (2/4)	25%	100%	100%	25%	75%	75%
Total	46% (11/24)	33%	83%	58%	37.5%	62.5%	83%

Stopping of Dental Fricatives

Phonemes	Probe 1 (Baseline 1)	Probe 2 (Baseline 2)	Probe 3 (Baseline 3)	Probe 4 (Gen. 1)	Probe 5 (Gen. 2)	Probe 6 (Gen. 3)	Probe 7 (Gen. 4)
/f-/	100% (4/4)	100%	50%	100%	100%	100%	100%
/v-/	100% (4/4)	100%	75%	100%	100%	100%	100%
/θ-/	75% (3/4)	50%	50%	50%	75%	75%	75%
/-f/	100% (4/4)	100%	50%	50%	0%	0%	0%
/-v/	100% (4/4)	75%	25 %	50%	0%	25%	25%
/-θ/	100% (4/4)	100%	50%	50%	0%	0%	0%
Total	96% (23/24)	87%	50%	67%	45.8%	50%	50%

Table 10. Participant A's Use of Final Consonant Deletion of Fricatives and Stopping in the Releasing Position Pre-, During, and Post-Treatment

Final Consonant Deletion of Fricatives

Treatment /-v/ (between Probe 3 and Probe 4); Treatment /-θ/ (between Probe 4 and Probe 5); Minimal Pairs Treatment /-θ/ (between Probe 5 and Probe 6)

Phonemes	Probe 1 (Baseline 1)	Probe 2 (Baseline 2)	Probe 3 (Baseline 3)	Probe 4 (Gen. 1)	Probe 5 (Gen. 2)	Probe 6 (Gen. 3)	Probe 7 (Gen. 4)	Probe 8 (Gen. 5)
/-f/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-v/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-θ/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-s/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-z/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-ʃ/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-ð/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/-ʒ/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
Total	100% (24/24)	100%	100%	100%	100%	100%	100%	100%

Stopping in the Releasing Position

Phonemes	Probe 1 (Baseline 1)	Probe 2 (Baseline 2)	Probe 3 (Baseline 3)	Probe 4 (Gen. 1)	Probe 5 (Gen. 2)	Probe 6 (Gen. 3)	Probe 7 (Gen. 4)	Probe 8 (Gen. 5)
/θ-/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/ð-/	---------	---------	---------	---------	---------	---------	---------	---------
/f-/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/v-/	75% (3/4)	100%	100%	100%	100%	75%	100%	100%
/s-/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/z-/	75% (3/4)	75%	100%	100%	100%	100%	100%	100%
/ʃ-/	75% (3/4)	100%	100%	100%	100%	100%	100%	100%
/ʒ-/	---------	---------	---------	---------	---------	---------	---------	---------
/tʃ-/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
/dʒ-/	100% (4/4)	100%	100%	100%	100%	100%	100%	100%
Total	89% (29/32)	93.7%	100%	100%	100%	97%	100%	100%

Table 11. Participant A's Addition of Vowels to Words Ending in Final Fricatives in Generalization Probes 3-5

Probe 3				
Phoneme	Number of Occurrences	Number of Opportunities	Words	% occurrence
/-f/	2	4	/ruf/ → / uwə /	50% (2/4)
			/lif/ → / lijə /	
/-v/	1	4	/sliv/ → / diə /	25% (1/4)
/-θ/	1	4	/riθ/ → / liə /	25% (1/4)
/-ð/	--------	--------	--------	--------
/-s/	0	4	--------	0% (0/4)
/-z/	1	4	/tʃiz/ → / tiə /	25% (1/4)
/-ʃ/	0	4	--------	0% (0/4)
/-ʒ/	--------	--------	--------	--------
Total =	5	24		21% (5/24)

Probe 4				
Phoneme	Number of Occurrences	Number of Opportunities	Words	% occurrence
/-f/	2	4	/ruf/ → / uɔ /	50% (2/4)
			/lif/ → / lijə /	
/-v/	0	4	--------	0% (0/4)
/-θ/	2	4	/mauθ/ → / maʊɔ /	50% (2/4)
			/riθ/ → / lioʊ /	
/-ð/	--------	--------	--------	--------
/-s/	1	4	/dʒus/ → / duə /	25% (1/4)
/-z/	0	4	--------	0% (0/4)
/-ʃ/	2	4	/liʃ/ → / lioʊ /	50% (2/4)
			/fɪʃ/ → / dɪjə /	
/-ʒ/	--------	--------	--------	--------
Total =	7	24		29% (7/24)

Probe 5				
Phoneme	Number of Occurrences	Number of Opportunities	Words	% occurrence
/-f/	1	4	/lif/ → / lijə /	25% (1/4)
/-v/	2	4	/faɪv/ → / daɪjə /	50% 2/4)
			/sliv/ → / lijə /	
/-θ/	1	4	/riθ/ → / lijə /	25% (1/4)
/-ð/	--------	--------	--------	--------
/-s/	0	4	--------	0% (0/4)
/-z/	0	4	--------	0% (0/4)
/-ʃ/	0	4	--------	0% (0/4)
/-ʒ/	--------	--------	--------	--------
Total =	4	24		17% (4/24)

Table 12. Participant A's Addition of Vowels to Words Ending in Consonants Other Than Fricatives, in Generalization Probes 3-5

Phonemes	Words
Probe 3	
/-ŋ/	/siŋ/ → /diə/
/-k/	/ʧik/ → /giə/
Probe 4	
/-ŋ/	/siŋ/ → /diə/
/-k/	/ʧik/ → /gijə/
/-t/	/fʊt/ → /doʊɔ/
Probe 5	
/-k/	/ʧik/ → /geɪə/

Appendix

Assessment Probe

/p-/ park paper pipe page	/-p/ ship top soup pipe	/b-/ bib bath bus badge beach	/-b/ bib web crib crab	/t-/ tire top tongue table	/-t/ cat gate foot shirt jet
/d-/ duck dog doll door	/-d/ third bread sled road	/k-/ car cat cage cow	/-k/ park duck cheek lock	/g-/ girl game ghost gate	/-g/ dog egg leg frog
/m-/ mouth mustache moth match	/-m/ lamb game vaccum thumb	/n-/ nail knife	/-n/ van sun thorn thirteen	/-ŋ/ tongue sing	/r-/ wreath roof road race
/l-/ leg lock lamb leash leaf	/-l/ doll shell nail table girl jail	/f-/ foot fish five finger	/-f/ knife leaf giraffe roof	/v-/ vegetables van vaccum vest	/-v/ five glove sleeve stove
/s-/ soup sing sun Santa Clause	/-s/ juice race bus grass	/z-/ zebra zoo zero zipper	/-z/ maze cheese Santa Clause sneeze	/ʃ-/ shell shoe shirt ship	/-ʃ/ fish mustache leash brush
/θ-/ thumb thorn thirteen third	/-θ/ bath mouth wreath moth	/tʃ-/ cheese chair cheek church	/-tʃ/ watch match beach church	/dʒ-/ giraffe jet jail juice	/-dʒ/ bridge cage badge page